Recycling wooden pallets: A case study of biochar production

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Agenda

1

Introduction & Welcome

- Who am I?
- Who is Edge Impact?

2

Why is LCA relevant to this project?

- Carbon sequestration and quantification

3

Biochar production

- Benefits of biochar production versus wood chipping

4

Q & A

- Questions & further info

Circular Economy & Lifecycle Thinking

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Pasindu has over 10 years of experience in sustainability, innovation, engineering, and project management. He is a Life Cycle Assessment Practitioner with a background in engineering and materials science, as well as several professional trainings in innovation, circularity and leadership.

Pasindu currently works on LCAs related to building products, consumer goods, manufacturing processes and product schemes, as well as the design and development of industry specific LCA tools.

About us

To fully transition to a sustainable society, commitments and targets are no longer enough. The warning signs have become frequent emergencies and disasters. Record temperatures, devastated communities, fires, floods and food shortages.

The message is clear: it's time to step it up and deliver, today.

But we don't see failure. We see opportunity. At Edge, we're working towards a world where unsustainable is unthinkable. We welcome the motivated leaders, organisations and industries who are looking to deliver positive global impact.

To make it happen, we combine science, strategy and storytelling. Ensuring everything we do helps our clients impact people and the planet positively. Because what matters most is the outcome.

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SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

What is biochar?

Properties

- **Carbon-rich** – crystalline structure produced by heating organic matter, typically between 400-700 ℃, in low or oxygen-free environments known as pyrolysis.
- **Highly porous** - the combustion of volatile organic compounds (VOC's) in the feedstock creates a network of interconnected micro cavities, producing a high surface area (SA).
- **Stable & inert** – the pyrolysis reaction and carbon content creates a highly ordered structure strongly resistant to decomposition and microbial degradation.

Differences to charcoal

Biochar is a type of charcoal produced at **lower temperatures** with **longer retention times** compared to traditional charcoal. These process properties result in:

- **Increased stability** - lower temperatures convert organic matter into 'recalcitrant' carbon that is resistant to microbial decomposition.
- **Increased porosity and surface area** – lower temperatures result in higher levels of molecules with different shapes, increasing SA through their shape diversity.
- **Increased absorption ability** – the higher presence of oxygen-containing functional groups enhance biochar's ability to absorb and retain nutrients and other soil compounds.

These properties make biochar well-suited for long-term carbon sequestration and as a soil amendment, among a variety of other emerging uses.

* www.southpole.com – "Removing carbon with biochar", 2022

Applications & benefits

Soil amendment

Biochar has a wide array of reported benefits when applied as soil amendment, including the below key examples.

Increased nutrient availability - biochar provides an inert and stable space for soil microbes to live and propagate.

Increased nutrient retention – biochar structure prevents nutrients from being washed away in rainfall or flooding events, and reduces leaching.

Increased moisture retention – biochar's high porosity holds water like a sponge, helping maintain soil moisture, especially in drought scenarios, while also reducing irrigation requirements.

Enhanced soil structure – provides air pockets, improves plant rooting and boosts mycorrhizal growth.

Greenhouse gas (GHG) mitigation

The production and application of biochar reduces GHG emissions from several angles, including:

Carbon capture - when used in applications that maintain the biochar's structure (i.e., not burnt as a fuel), biochar captures approximately 50% of carbon held in the original biomass[1].

Increasing soil organic matter (SOM) levels – when added to soil, biochar can improve the soil's physical, chemical and biological properties, which can increase SOM levels.

Decreased reliance on fossil fuel derived fertilisers, pesticides and herbicides – through its nutrient retention properties, biochar reduces chemical input requirements and builds nutrient availability over time.

Decreasing potent GHG emissions – large amounts of nitrous oxide can be released when nitrogen fertilisers are added to acidic soils. Biochar absorbs nitrogen, decreasing the severity of these emissions.

Composting

Adding biochar to compost can **accelerate the composting rate**, increasing throughput capacity with no infrastructure upgrades, while also reducing associated GHG emissions[6].

The resulting product is then a **superior product** of biochar charged with nutritious compost ready for soil application.

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[1] - *https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12889*

Applications & benefits continued

Environmental remediation

Studies show the most dramatic yield improvements using biochar as a soil amendment occurs in low-nutrient, acidic, sandy and recycled soils. Beyond crop yields, this does position biochar favourably for soil remediation in several scenarios, including:

- **Remediation of contaminated soils** – biochar's high surface area and porosity can absorb contaminants and prevent them from leaching into ground water
- **Restoration of degraded lands** – by improving soil quality and enhancing plant growth, biochar can help prevent soil erosion and desertification.
- **Restoration of contaminated aquatic environments** – by absorbing contaminants, biochar can reduce the bioavailability of toxins to aquatic life and prevent them from entering the food chain.

Animal feed

When integrated into the diets of livestock, biochar is found to improve animal health by increasing nutrient intake efficiency, regulating weight, removing contaminants and thus increasing livestock productivity. Literature also shows in most studies for all animals tested, positive effects on parameters including:

- Toxin adsorption
- Digestion
- Blood values
- Feed efficiency
- Meat quality
- GHG emissions

This is a relatively new area of research with more established markets and products in the USA (e.g., Airex Energy) and Europe (e.g., Terramanna).

Other emerging areas

There are several emerging areas biochar is being applied, including:

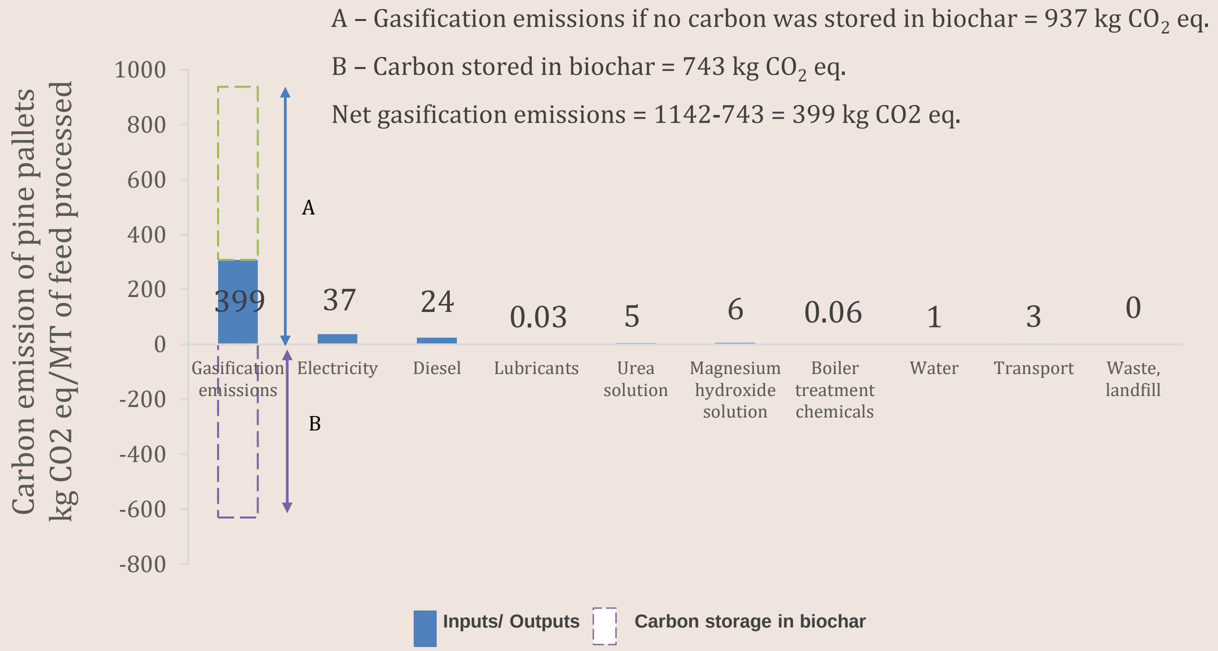
Water filtration – biochar can absorb contaminants (e.g., heavy metals, organic pollutants, and pathogens) and provide a habitat for beneficial microbes to break down and remove water contaminants.

Sustainable cement – biochar is being studied for application in cement in an effort to reduce the significant carbon footprint of cement production. Studies find that cement properties and performance can also improve, along with the sustainability performance.

WHY LCA IS RELEVANT

Pallet production and gasification at end-of-life

- LCA helps quantify the carbon emitted and sequestered throughout the lifecycle stages of pallet production and their end-of-life scenarios.
- In this scenario, we quantify the emissions associated with gasification as the EOL pathway.
- Carbon sequestered in the biochar product reduces the carbon intensity of the gasification step down to 399 kg CO2 eq per tonne.


A – Gasification emissions if no carbon was stored in biochar = 937 kg CO_2 eq.

B – Carbon stored in biochar = 743 kg CO_2 eq.

Net gasification emissions = 1142-743 = 399 kg CO2 eq.

Pallet production and gasification at end-of-life

- This breakdown accounts for the processing/ harvesting, transport and gasification system carbon impacts, resulting in **1142 kg CO_2 eq released per tonne of feedstock.**
- The sequestered component represents **65%** of the total process CO_2 eq.
- To compare against other EOL scenarios (e.g., mulching, landfill, incineration and natural decomposition), further LCA research into the impacts of those scenarios will be required.
- This assessment does not account for impacts associated to biochar's specific application, whether it be to land, in filtration, within cement, or other application.

		kg CO_2 eq.			
Stage	Emissions category	N_2O	Fossil w/o N_2O	Biogenic	Total
1	Processing/ harvesting	0.2	16.6	0.04	17
2	Transport	0.03	2.95	0.01	3
3	Closed-circuit system (w/o biochar storage)	7.4	70	302	379
	Biochar (carbon sequestered)	*n/a*		743	743
	Closed-circuit system (w/ biochar storage)	7.43	72.95	1045	1125
	Total (all stages)	7.63	89.5	1045	1142

Source – Pyrocal CCT LCA

FUTURE WORK

Further areas of study

Comparison with other EoL scenarios

As mentioned previously, this study does not compare Biochar's environmental performance against other forms of EoL, such as landfill, natural decomposition, incineration, etc.

Analysis of these scenarios will allow for objective comparison and evaluation of Biochar as an environmentally viable EoL option for wooden pallets.

Future energy mix

This study does not take into account the future electricity mix, and the increased use of renewable electricity within it.

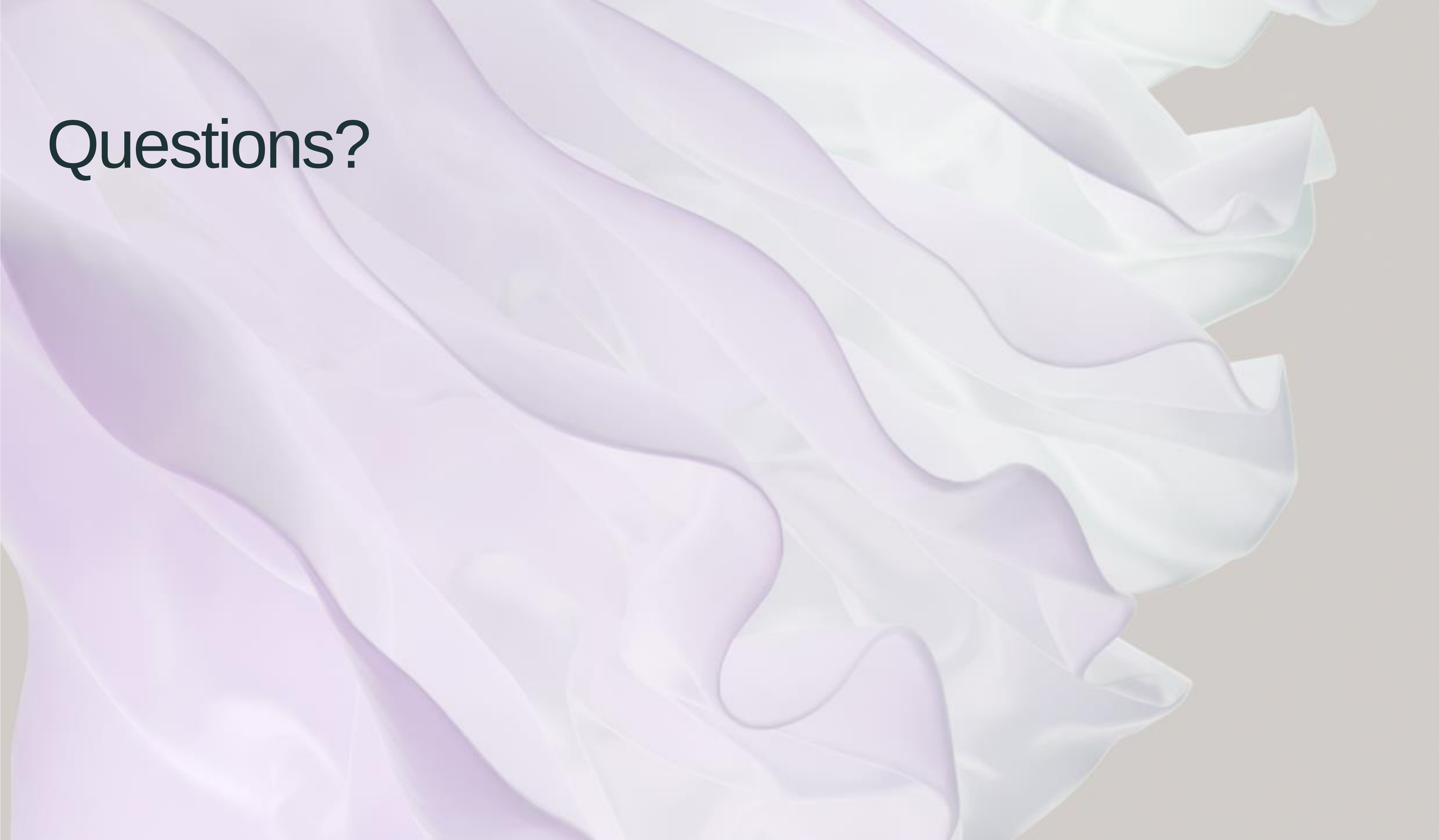
Incorporating this future state in the LCA will further the case for biochar as a recycling option for wooden pallets as the electricity is a considerable contributor within the total process.

End use comparisons

The relative impacts of the use of biochar in final application has not been quantified within this study.

This quantification will provide an understanding of the best use of biochar from an environmental perspective. This comparison could also result in an LCA tool which stakeholders may use to make informed decisions at EoL of wooden pallets and during biochar production.

Questions?



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